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ORIGINAL ARTICLES.

Collapse Structures.

By J. V. Harrison and N. L. Falcon.[1]

Introduction.

RECENT reconnaissance surveys in south-west Persia have brought to our notice many examples of enigmatical structures preserved in massive limestones beautifully exposed in the naked mountains of that region. Application of many hypotheses involving faulting and thrusting proved impossible to satisfy the facts we had observed. We were at length forced to explain some of the structures we encountered as being produced by collapse of great sheets of limestone after removal of their original supporting cover accompanied by unsticking from their basement. Gravity alone provided the motive force. Simple folds, erosion, a shaly substratum, and gravity have induced massive beds of limestone to behave in an entirely unexpected manner. Examples are described below with sketches.

Not only have massive limestones been bent into comparatively sharp but apparently unbroken folds at the surface of the earth under no cover whatever, but large masses have been let down a mountain side so tenderly that the sheet was not disrupted by its move. Collapse of a similar nature provides a hypothesis which will explain the formation of the wonderful tongue-like salt-plug glaciers, the mechanics of which had provided the authors with a previously unsolvable problem, and also some of the gypsum flow sheets of south-west Persia.

Surface Creep.

The best-known and generally accepted phenomenon produced by the action of gravity upon rocks which are exposed in steep slopes is " creep ". James Geikie drew attention to the movement down hill of soils. In such plastic and poorly consolidated rocks as clays and sands "creep" has been observed in surface excavations to a considerable depth. In Trinidad on any but an extensive flat surface pits showed that the clays and silts are folded by creep usually for 10 feet and sometimes more than 20 feet from the surface.

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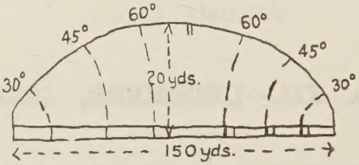

In a cutting made for a railway from Puerto Solches to Bucaramanga in Colombia thin-bedded limestones interstratified with shales showed a strange fan-shaped arrangement in a vertical section which would have been difficult to interpret but for the drain at the base of the section where the strata were exposed vertical throughout. In this section beds of limestone 12 inches thick had suffered bending with the production of anomalous surface dips solely from the effects of gravity. Examples could be multiplied indefinitely and are widely known from all over the world.

STRATIGRAPHY IN KUHGALU, PERSIA.

In Kuhgalu, the district of mountainous Persia, where many sections show these peculiarities, the beds involved are as follows :—

			feet.
1. Miocene	Fars	Red sandstone and silts, grey marls, anhydrite (gypsum near surface), and marls	ca. 10,000
2. Lower Miocene	Asmari Limestone.	Bedded and multiple-bedded limestones above with massive limestones below	ca. 1,000
3. Eocene and Upper Cretaceous.	Pre-Asmari Marls.	Grey-green silts, marls, and marly limestones	ca. 2,000
4. Middle Cretaceous Limestone.		Massive Rudist Limestone or thin-bedded *Globigerina* limestone.	ca. 3,000 or ca. 1,500
5. Albian		Ammonite marls	ca. 1,000
6. Pre-Albian Limestone.		Massive limestone	more than 3,000

The Fars, the pre-Asmari Marls, and the Albian Marls are formations which have weathered into strike valleys. The Asmari Limestone, the Middle Cretaceous Limestone, and the pre-Albian Limestone offer resistance to weathering and protrude as strike ridges and rounded domal ranges.

PERSIAN KAINOZOIC OROGENESIS AND WEATHER ETCHING.

In post-Miocene times south-western Persia was compressed and a wide strip of country thrown into wrinkles with a north-west–south-east strike, the wrinkles being in general tighter north-eastwards and more widely spaced south-westwards. Most of the folds are approximately symmetrical and shaped in section nearly as sine curves.

When the country had been folded vigorous erosion occurred stripping many of the folds in Kuhgalu almost completely of their cover of Fars, and leaving others with a veneer in the synclines. The country thus produced has now a dissection between mountain summits and valley bottoms averaging 5,000 feet, but examples occur where the difference in height is about 8,000 feet. At an earlier stage it may have reached 12,000–14,000 feet. The amplitude of certain folds is of the order of 15,000 feet.

At the present stage the Asmari Limestone has been sometimes extensively weathered, so that the Middle Cretaceous Limestone, exposed by the rapid removal of the pre-Asmari Marls, now remains as smooth elongated dome-shaped mountains with elliptical ridges of Asmari Limestone enclosing them. In some mountains the pre-Albian Limestone outcrops with a double ring of limestone ridges around it (Fig. 1).

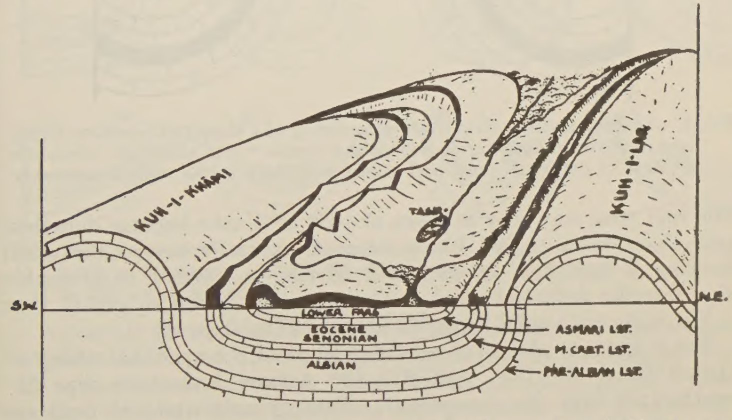

Fig. 1.—Simplified diagram to show the nature of the overturns in the Asmar Limestone of the Tasir Syncline. Not to scale.

COLLAPSE STRUCTURES ALONG STRIKE VALLEYS.

When the Asmari Limestone or Middle Cretaceous Limestone had been eroded out, and left standing up as a knife edge or dome, all was regular so long as too great a body of unsupported rock did not protrude. After the projecting column exceeded a height of about 2,000 feet it tended to become unstable, and in spite of the robust aspect of the limestones they suffered collapse through bending or breaking. The resultant structures such as " roof and wall " ," cascades ", " flaps ", and slip-sheets are abnormal, but if considered in only one cross-section might be considered as results of strong tangential forces.

Roof and Wall Structure due to Gradual Slip.

Consider a section through a denuded sine curve mountain (Fig. 2). When once the crest of the dome is broken by weathering the sheets of limestone tend to move apart under the force of gravity by slipping over the underlying shales. This pushes the walls out and produces a section like the gable-end of a cottage in which gently dipping limestone is found lying upon steep or vertical limestone, the roof meeting the wall with a sudden change of dip, or, in extreme cases, being separated from it by a low angle thrust plane. Beds of limestone of a lower formation still retain their original sine curve shape.

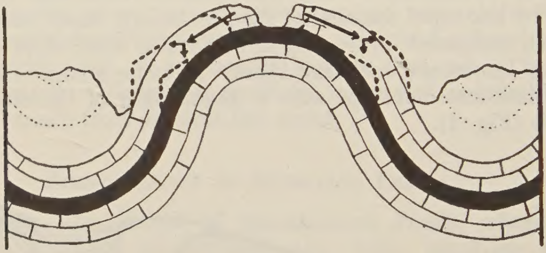

Fig. 2.—Diagrammatic section to show tendency of a Massive Limestone formation to slip on underlying shaly beds and form a " roof and wall " structure. Erosion of anticlinal crest and presence of deep strike valleys necessary.

The roof part may stay in place or part of it may become detached and slide down. The block released normally rattles down-hill forming a landslide of detached blocks—a normal catastrophic slip, but the detached block sometimes is let down so gently that it lies below as a solid unruptured mass (Fig. 3, *g*, *m*).

For a distance along the northern slope of the synclinal valley of Qal'eh Raisi (31° 13′; 50° 30′) the Asmari Limestone dips 25° southwards from its escarpment. Fars gypsum and red beds are exposed along the axis of the trough. A large sheet of Asmari Limestone dipping 10° south fills the northern half of the valley and was seen lying with its one end resting upon the rooted-limestone slope to the north and its other upon the Fars gypsum and marls. This slab is about 4 miles long in the direction of the valley and $1\frac{1}{2}$ miles across. The only distinctive feature of the limestone is that it weathered somewhat rusty brown and has not the usual sharp bedding lines where the streams have cut gullies into the sheet. The bedding is, however, still clearly discernible.

Another type of slab structure is found where the slipped slab has maintained a much higher dip (Fig. 3, *g*). For example, a long irregular chain of limestone lies between a normal Asmari ridge on the north side of the Nurabad River (30° 10′; 51° 25′) and a wide expanse of conglomerate. From the stratigraphy it is clear that the base of the Asmari of the outer chain is in contact with the top of the normal one. This relation can only be explained by a higher part of the original wall having been dropped like a theatre curtain in front of the rooted sheet.

Cascades.

Sometimes the outer layers of the dipping sheet of limestone sag producing a cascade (Fig. 3, *j* and *p*).

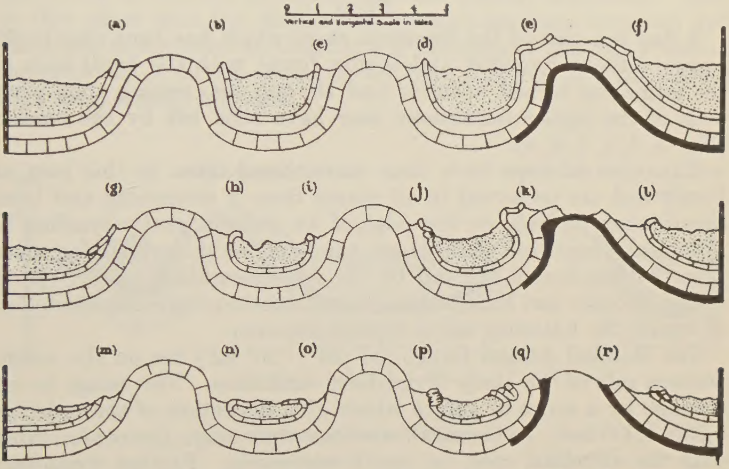

Fig. 3.—Composite Sections. Diagrammatic, and simplified to show development of structures. These figures are quoted in the text as types, not as the actual examples.

A cascade may be defined as one or more asymmetrical subsidiary wrinkles developed upon a simple dip slope. In its simplest form an example is preserved in Tang-i-Narak (30° 22′; 50° 56′) where a slope of pre-Albian Limestone has an overall dip of about 25° a short distance above the valley floor. A gully cut in this slope exposes the lower beds smoothly sweeping downwards, but at the top a single sheet of limestone about 10 feet thick has slipped downwards over inter-bedded shaly marl and formed a single wrinkle on the hill-side.

Near Basht, on the south-western flank of Kuh-i-Duhak (30° 16′; 51° 14′) which is formed by a simple anticlinal fold in the Asmari Limestone showing no disturbance for several miles along the strike, three wrinkles develop at the south-eastern end. These only affect the upper 400 feet of the formation in which thin marls are interbedded with the sturdy limestones.

The lower part of a 2,000 ft. dip slope of Asmari Limestone at Chulbar (32° 22′ ; 49° 22′) forms a cascade of unbroken wrinkles which are produced by sagging of the upper 400 feet of the formation. A gash valley here exhibits the underlying beds dipping regularly at about 40°, while in the wrinkles dip twice changes continuously from nearly zero to 90°.

The whole thickness of the same formation is corrugated at its base on the north-eastern flank of Kuh-i-Mungasht (31° 40′ ; 50° 10′). At one time the limestone was in place 11,000 feet above the present cascade which can be observed for some miles along the left bank of the Karun River.

Flaps.

A flap is a part of the limestone sheet which has bent over backwards without breaking and is now found with the basal beds of the formation turned upwards and the top ones resting upon what beds of the higher formations may have been left by the erosion (Fig. 3, *h*, *i*, *l*, *n*, *o*).

Examples of flaps have been encountered often in this part of Persia and are preserved in all stages from a steepening and local overturning of beds on the edge of an orderly gentle syncline to a typical recumbent fold where the syncline is covered for more than 2 miles across the dip by the superincumbent sheet. Both Lower Miocene and Middle Cretaceous Limestones provide examples, of which the following are a typical selection.

The Mambal Asmari Range (31° 20′ ; 50° 22′) lies on the south-western side of the steep Kuh-i-Barfi anticlines. This range is cut through by a series of gorges which give dissection of the order of 3,000–4,000 feet. To the north-west the whole ridge dips conformably with the anticlinal core, i.e. south-westwards. Farther south-east the basal part as seen in the gorge conforms and is approximately concentric with the Middle Cretaceous Limestone core, but when traced upwards the limestone steepens to vertical and is then seen to overturn until the apparent dip is 35° northwards (Fig. 2 cf. 1).

As the Tasir (30° 36′ ; 50° 51′)–Tul-i-Chaghah (30° 32′ ; 50° 57′) syncline is traversed from north-west to south-east the syncline is at first found to be a normal if steep sided trough, above which, on the south side, rises a well preserved unbuckled knife-edge ridge called Kuh-i-Fat (30° 34′ ; 50° 52′). (Figs. 1, 4). Still farther south-east the bold ridge can no longer be discerned, but in its place is a round topped limestone hill, Kuh-i-Serak (30° 32′ ; 50° 55′). A stream section on the south-eastern side of Kuh-i-Serak reveals that this flap lies nearly horizontal and upside down for about 2 miles and it then bends without visible fracture through nearly 180° to form the normal floor of the syncline. This flap forms a typical recumbent fold for about four miles along the strike and

2 miles across it. Traced farther east to Audehgah (30° 25′ ; 51° 1′) the flap has disappeared and the attitude of the Lower Miocene Limestone is again that of a normal toothed-ridge with its dip conforming to that of the well-exposed pre-Albian Limestone core to the south-west. In the section from Tasir to Audehgah this pre-Albian Limestone pursues a normal course, sweeping down in a regular curve from the summit of the 11,000 ft. mountain of Kuh-i-Khami (30° 31′ ; 50° 52′) under the synclinal filling and emerging regularly as Kuh-i-Barham Shah and Kuh-i-Lar (30° 35′ ; 50° 57′) on the other side of it. The Lower Miocene ridge, however, on the north-east of the syncline is only regular from Tasir to near Lar, beyond which it also becomes overturned near Tul-i-Chaghah. It is striking here that south of Lar there is a deep valley between the Middle Cretaceous Limestone and the Asmari Limestone. Only at this point does the Middle Cretaceous Limestone overturn and elsewhere it conforms to the shape of the core of the fold ; and in the same line of section across the dip from this overturn the Asmari beds are normally disposed.

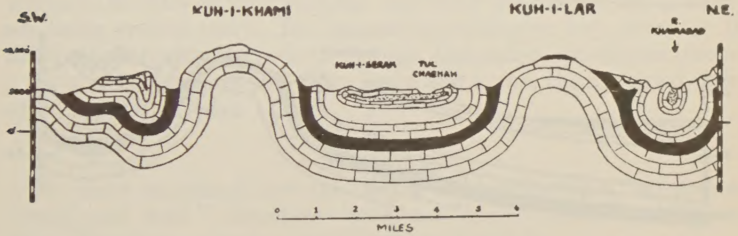

Fig. 4.—Tasir Syncline.

There are many other fine examples which might be described but only the case of Kuh-i-Shah Nishin (29° 50′ ; 51° 45′) will be mentioned here. In front of this anticline, on the south-western side, lies a wide gentle syncline. The Asmari range runs for some miles from the north-western plunge as a gentle dip-slope and scarp feature, with a dip of about 15°. Inside it the Middle Cretaceous Limestone forms a regular smooth dome with its girdle of Eocene Marls not deeply eroded. Near Samgun (29° 52′ ; 51° 41′) (Fig. 5*b*) the Eocene Marls are more deeply eroded in a strike valley between the Asmari range on the south-west and Middle Cretaceous Limestone on the north-east. As the depth of this valley from the cols to south-east and north-west increases to a maximum at Samgun so the curve of the Middle Cretaceous Limestone surface departs from regularity. Behind the village it lies with reversed dips of 35° whilst on either hand passing towards the cols it stands vertical. The Albian beds exposed nearer the axis however are folded into as smooth a sine curve as the Middle Cretaceous Limestone itself assumes at the cols.

Farther south-east near Naudan (29° 47′; 51° 43′) (Fig. 5*a*) the dip of the Asmari Limestone increases and a flap of it is folded back for a distance of 6 miles along the strike and 2 miles across it. A stream has cut through and exposed the Fars gypsum trapped below the limestone flap. At this longitude the Middle Cretaceous Limestone is present and visible as a smoothly rounded arch. Still farther to the south-east the Asmari Limestone is exposed for many miles and lies in places oriented normally and in places as a flap.

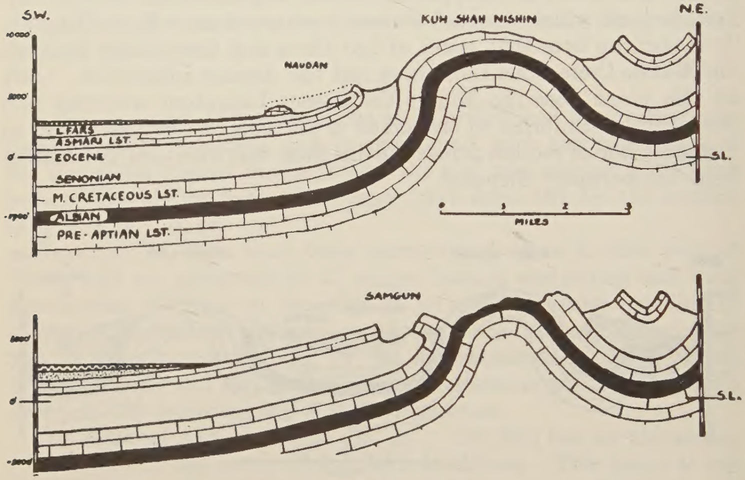

FIG. 5.—*a* (above) Asmari Limestone overturned, Middle Cretaceous unaffected. *b* (below) Four miles north-westwards; Asmari undisturbed, but Middle Cretaceous Limestone has turned over.

This variation in the posture of the limestones along the length of one fold depended upon the amount of local differential erosion at any point. Where erosion was sufficient to allow gravity to play its part sectors of beds originally folded concentrically together later moved independently to produce the different structures now preserved.

Complex Structures.

The examples described above are relatively simple structures induced by a single type of movement after erosion has progressed so far in the removal of cover. Sometimes, however, a complex of isoclines with faults between them is found on the flanks of the big Persian mountains. Some of these also may be explained by a combination of folding and faulting caused by gravity (Fig. 3, *e*, *k*, *q*).

Flat Profile "Glaciers" in Salt-Plugs.

These narrow tongue-like "glaciers" associated with salt-plugs in South Persia (7)[1] can now be explained as collapse features from salt-plug mountains directed by erosion of their retaining wall of sediments. The fallen sheet which was at first made up of salt, gypsum, and exotic blocks is leached in due course until only gypsum and the igneous rocks are left. In the steep salt-glaciers, where salt still forms a big percentage of the whole mass, gliding along crystals may play a part in movement, but normal collapse may be active here too.

Flow Sheets of the Lower Fars Gypsum Series.

In the foothill region of south-west Persia sheets and tongues of the very incompetent Lower Fars gypsum series frequently spread out from anticlinal cores over the competent Middle and Upper Fars forming the lower ground of the synclines. Some of the sheets are undoubtedly caused by collapse under the action of gravity (cf Fig. 3, *a*, *g*, *m*). The top of the Lower Fars contains limestone beds which are sometimes thick enough to act as a stiffening to support the sides of the anticlinal core while the beds of the syncline are being eroded away. The supporting walls give way, however, if differential erosion proceeds far enough, and under suitable conditions a mass of Lower Fars will move down and across the upturned beds of the synclinal edge.

Mechanics.

We have explained how the sliding of the mountain roof causes "roof and wall" structure—with a "knee" between different dips. Breaking at such a knee leads to slip-slabs.

We picture a flap forming with the overbalancing of a steep limb, followed by progressive growth as the outside cover and support is removed through erosion. It does not appear to be possible that a flap like Kuh-i-Serak can have been formed by one sudden collapse of a huge limestone wall, but was a gradually growing feature.

The flexibility of a massive limestone which has been bent through 180° is best explained (in the absence of exact knowledge) as the effect of jointing, although the weakness of calcite under stress may possibly play its part also.

CONCLUSION.

In Persia we have good exposures and a suite of unequivocable examples which we have seen and mapped, and illustrated by photographs, sections, and diagrams.

In another part of the world we have seen large collapse structures in Cretaceous Limestones in the Eastern Andes of Colombia.

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[1] The numbers in parentheses refer to Bibliography at end of paper.

Studying literature we find many sections which may be reconsidered in the light of the collapse of simple folds under gravity.

In the Alps of Savoy sketches and sections drawn by Collingwood (3) almost match gravity folds in Persia ; an especially good case being that of Mount Couz and the mountains between Thonens and the River Borne.

Sundry folds in the Jura as depicted in the sections by Alb. Heim (8) suggest that gravity played its part after simple folds had been formed and their cover denuded, e.g. Taf. xxii, No. 5, Weissenstein Kette ; Taf. xxiii, No. 7, Rangiers Kette ; Taf. xxiv, No. 15, Mont de Marnaud, and the diagrams on page 582 represent structures which in part could be due to collapse.

In Spain Douvillé (5) depicts a section with a strange knee bend which may be superimposed gravitational effect in a section of folded Carboniferous to Liassic sandstones, conglomerates, marls, and limestones.

A section by Blackwelder (2) through the Ouachita Mountains in Arkansas shows two structures which may have been produced at one period by collapse.

The north–south section across Lizard Creek on the western side of the Elk River in the Rocky Mountains drawn by Telfer (15) is also suggestive. In it shales, quartzites, and limestones from Trias to Devonian are involved.

New Zealand (11) and South Africa (12) provide anomalous structures in which collapse may have been the creative force. The same applies to the section at Derbent (13) through the Caucasus.

In Persia we have seen and mapped thrust faults produced by tangential forces ; but we have now recognized this group of anomalous structures which we regard as having been produced at the surface from simple folds after denudation by the action of gravity.

Daly (4), de Terra (15), Haarmann (6), Bain (1), and Sherrill (13) all see in gravity a factor causing mountain folding, and Jeffreys (9) has suggested that structures comparable to those found by us have occurred on a very much larger scale.

Finally we aver that gravity acts upon fold-mountains in being, causing secondary complications superimposed upon the simple folds.

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On the Effect of the Mino-Owari Earthquake of 1891 on the Seismic Activity of other Districts in Japan.

By Charles Davison, Sc.D., F.G.S.

THE sudden movement that causes a great earthquake must alter the conditions of strain in the surrounding crust. The strain may be increased in some regions and decreased in others and the changes may be great enough to precipitate or prevent the occurrence of what Mr. Oldham has called "sympathetic earthquakes". It thus becomes of some interest to ascertain how far the influence of a great earthquake may extend from its source, and the present brief note is an attempt to examine this point in the case of one well-known and well-studied earthquake, that of Mino-Owari in Japan on 28th October, 1891.

The fault-scarp formed with this earthquake was 70 miles in length. Along the southern portion of 40 miles, the relative movement of the crust on the north-east side was to the north-west, in one place, by as much as 13 feet. In the vertical direction, the relative movement of that side was downwards, the maximum being 10 feet, except in one spot near Midori, where the crust rose as much as 20 feet.

In a paper published nearly forty years ago in this journal,[1] I examined the effect of this earthquake on the seismic activity of the adjoining districts. This paper, like the present note, is founded on Professor Milne's valuable catalogue of 8,331 earthquakes in Japan during the years 1885–1892.[1] The method used in both is to ascertain the mean monthly numbers of earthquakes in certain districts during the two intervals 1st January, 1885, to 27th October, 1891, and 1st November, 1891, to 31st December, 1892, and to calculate the ratio of the latter numbers to the former. In two districts, one about 33 miles north-east and the other about 67 miles south-west of the fault, the ratios were as much as 6·1 and 10·4 respectively. There can be little doubt, it would seem, that these increased activities were due to the occurrence of sympathetic earthquakes.

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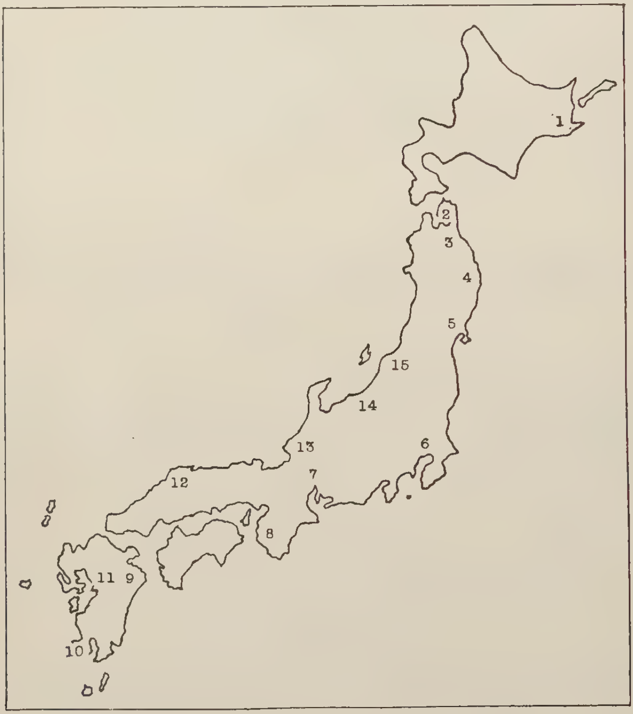
[1] Geol. Mag., XXXIV, 1897, 23–7.



The point that I now wish to examine is whether a similar influence can be traced to greater distances. Milne divided the whole of Japan into fifteen districts, the centres of which are marked by the numbers in the sketch-map. The main fault lies in district 7 and its continuation in district 13. In the following table, the second and third columns give the average monthly numbers of earthquakes during the intervals before and after the earthquake, and the fourth column the ratio of the latter number to the former.

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[1] *Japan Seis. Journ.*, iv, 1895, 1–367.

	Average monthly numbers		
District.	*before.*	*after.*	*Ratio.*
1	3·54	3·50	1·0
2	1·26	·64	·5
3	·61	2·21	3·6
4	·72	·57	·8
5	1·94	7·00	3·6
6	14·84	14·43	1·0
7	4·20	228·07	54·3
8	2·17	3·21	1·5
9	1·35	2·14	1·6
10	2·06	1·14	·6
11	4·06	3·79	·9
12	1·28	·57	·5
13	·28	6·71	24·0
14	·62	1·64	2·7
15	·79	·07	·1

The fourth column shows how greatly the activity was increased in the two districts (Nos. 7 and 13) along the fault-line. In three others (Nos. 3, 5, and 14) there was a moderate rise, and in two (Nos. 8 and 9) a slight rise. In four (Nos. 1, 4, 6, and 11) the activity was practically unchanged, while in the rest (Nos. 2, 10, 12, and 15) it was reduced.

The increases in the three districts 3, 5, and 14 are clearly due to the after-shocks of rather strong earthquakes that disturbed areas of more than 5,000 sq. miles—on the 13th and 15th December in district 3, on 20th November in district 5, and on 6th November in district 14. These four earthquakes may themselves have been effects of the Mino-Owari earth-movements, but as three such earthquakes occurred in the same districts (24th November and 8th December in district 5 and 4th December in district 14) in 1888, and as there was no change in the sensitive district 6 that includes Tokyo in 1891, it would seem that the effects of the movements in producing sympathetic earthquakes were confined to within a distance of about one hundred miles.

“The Anatomy of the Earth”—A Seventeenth-century Cosmogony.

By F. J. North, D.Sc., F.G.S.

THE theories of earth-formation and earth-structure of which the seventeenth century was so prolific, are illustrated in the works of Woodward and Burnett, of Ray and Steno, and others who are usually cited when the history of geology is being discussed, but occasionally one meets with a cosmogony that seems to have remained unnoticed by subsequent writers. In such cases the neglect is, no doubt, to be attributed to the fact that some of the views put forward were too preposterous to command serious consideration even in days when speculation and credulity were more rife than observation and common sense : and if a book was not discussed by contemporary writers it would, in all probability soon join the limbo of things forgotten. This seems to have been the fate of a little pamphlet entitled *The Anatomy of the Earth*, written by Thomas Robinson, Rector of Ousby, in Cumberland, and " printed for J. Newton, at the Three Pigeons in Fleet Street " in 1694.[1]

His theories are so unlike those put forward by his better known contemporaries, his arguments so unscientific, even in an unscientific age, and his conclusions so naïve, that, having been brought to light during inquiries relating to the history of geology, it would seem a pity to consign the work again to oblivion.

Dedicating the work to the " Gentlemen Miners ", he wrote : " I could not direct this small Treatise, unto a more suitable Patronage, than by devoting it to your Fraternity ; the Contents of it, aiming at the more hidden, as well as visible Parts of the Earth. And the Opportunities I have had, of being sometimes Underground . . . will, I hope, plead my Excuse, if I attempt Philosophically to describe those several Metals, Mines, and Minerals . . . which a Mechanick relates only by Rott : It is not out of any great conceit of these Notions, that I have been bold to make them publick, or Dedicate them to you ; but out of a strong desire to set some greater Wits on work, to Improve the Subterranean Philosophy ; . . . I am, in the mean time Gentlemen, your hearty Well-wisher and humble servant, Tho. Robinson."

Chapter 1, entitled " Of the Creation of Matter ; the reducing it into Form and Order ; and the infusing a Vital Spirit into it ", comprises only the following general statement : " The first part that the Almighty created of this *Sublunary World* was *Matter* ; which consisted of innumerable Particles of divers Figures and different Qualities, running a Reel in a dark Confusion. In this State they continued, bound up and hamper'd with a vast thick Fogg or Mist of a waterish substance, extending it self as far as the Moon's Vortex, until the *Spirit of God moved upon the Face of the Waters*, or (as the word in the *Hebrew* signifies) *sate on brood* on the rude Mass, and, by vital Heats and Incubations, did digest into an orderly World : by whose infusing into it, and every part of it, a vital Spirit, it became a great *Animal*, having Skin, Flesh, Blood, Bones, Nerves, etc."

In subsequent chapters the comparison between the earth and a living body is developed by considering, in turn, the skin of the animal, which is of course, the soil ; its flesh—the layers of clay, gravel, and sand beneath the soil ; its blood, which is represented by the waters that flow through passages in the flesh ; its bones, which are the mineral veins that strengthen the flesh ; its sinews and ligaments which are the dykes and "strings" that bind the bones together ; and finally its belly, from the "intestine wars" in which proceed hurricanes and earthquakes, when the earth is afflicted with ague and distemper.

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[1] In addition to the copy upon which note is based, the only others I have as yet been able to trace are in the British Museum Library and in the Banksian Library—for the latter record I am indebted to Dr. C. Davies Sherborn.

The chapter on the skin of the earth discusses not only the nature of that integument, but also the origin of living things. It contains some novel views upon the subject of spontaneous generation, and solves all difficulties concerning the origin of life in a delightfully simple manner. It begins : "The Outer Coat and Surface of the Earth is its *Skin* ; which (being concocted and digested by the influence of the Sun's Beams, and having a *Plastick power* infused into it by the *Spirit of Nature*) became productive not onely of Grass, Trees and other Vegetables, as the Skins of other Animals naturally grow hairy ; but, when it was in its full strength and vigour, it brought forth all kinds of Birds, Beasts and Serpents, as naturally as it now brings forth divers kinds of Insects, or, as the Skins of other Animals bring forth lice."

"For the influence of the Sun (which the old Philosophers called the *Spirit of Nature*) striking upon the passive Matter, did, by vertue of its plastick and vivifick Quality, modifie it into such a Figure, as that it necessarily drew down the Seminal forms of all kinds of Vegetables ; as a Load-stone draws Iron to it, when it comes within the Sphere of its Activity. Thus all sorts of Plants began first to peep out of the Earth, as Corn out of the Furrows ; which, retaining Seed in themselves, did afterwards propagate their own Species by univocal Generation."

Later on a second manifestation of the Spirit of Nature "drew down . . . the seminal forms of all Beasts Birds and Fishes and Insects", while a third "did modifie matter into a yet nobler form" — man !

At this point the author ventured upon what must, at the time, have been rather dangerous ground, for, he said, "The first Individuals of this noble Species were called *Adam* and *Eve*. Yet whether by *Adam* and *Eve* are meant single persons : or a whole Generation of Men and Women, which stock'd all the World at once ; or, by *Adam* is to be understood onely the rational and Masculine Faculties of the Soul, and by *Eve* the Feminine and subservient, I leave to those who pretend to knowledge in mystical Philosophy. . . . Onely ; It may be urged, by way of Argument, that if Blackness be natural to the Aethiopian, and Whiteness to the European, they do not derive their Original from one single Person ; but, instead of that, it seems probable that the different Soyls, or various Modifications of Matter in several parts of the World, produced Men of different Colours and Complexions."

Another startling suggestion is that while the creation of the higher forms of life was limited to those early manifestations of the Spirit of Nature, the earth's skin still continues to produce certain lowly forms, for "The Mountains and Planes being thus replenish'd with Grass, Plants and Fruits; the Forests with Beasts; the Air with Birds; and the Seas and Rivers with Fish; *God cursed the Earth*: that is, so weakened its plastick power, that it could no longer (*proprio motu*) bring forth the more perfect and noble kinds of Creatures. But those inferior and imperfect Animals which we call *Insects* it still affords us, when even the Matter is so modify'd, by the different degrees of heat, as to be capable of such Productions. Hence the several Months of the Year produce their several sorts of Flyes; as *May*-flyes, *June*-flyes, or *Bracken-Clocks*, and the like: Nay, every hour of the day hath its special kind of Flyes, as the heat increases or decreases."

Although he called insects "inferior and imperfect animals" he attributed to them quite an important part in Nature's economy for, "as God made all the other Creatures, of an inferior Rank and Order, for the Use and Service of Man; so all these Monthly, Daily, and Hourly Productions of Insects, etc., are no less for his Benefit. . . . For, as Toads and other venomous Animals suck up those poysonous Vapours, which, if dispers'd through the Earth, would infect the Plants, and prove destructive to humane Health, if not of Life it self; so Flies and other Insects feed upon the Corruptions of the Air, which might otherwise contribute to the causing of many malignant Distempers." It was a common failing in those days to reverse what we now know to be cause and effect!

Robinson's observations upon the "Flesh" and the "bones" are rather less to the point, for the chapter on the latter is really an attempt to provide a classification of metals and minerals. He subdivides them into *Noble* and *Ignoble*, and those of the latter class he assigns to three principal kinds: (1) Terrene; these "are of a round Grit, which will not calcine, they are either "Red, White, or Mixt, and the Perfection or Quintessence of 'em is Iron-stone". (2) Unctuous and Pinguid; these, which include limestones and marble, will calcine, and are underlain by "grey freestone mixed with sulphur", beneath them is a grey metal "which turns quickly into another fat and black one, and immediately leads to *Coal*, the Perfection of this Sort of Stones". (3) Hot and sulphureous; these are spangled with sulphur and occur in association with metals.

Noble stones also are reduced to three kinds—"Transparent, Resplendent and Opake." The transparent stones—evidently crystals—"are Excrescences or Superfluities of Stones of a Fiery Nature; as Gums are of the natural Succus in several Trees of a hot quality," while "the most useful of all opake stones is the Loadstone. . . . Tis *Multum in parvo*; for in it the Spirits of the whole Mine concenter; whence, continually emitting their *Effluvia*, they attract Iron by Sympathy. For, as the Roots of Plants have an attractive Faculty whereby they suck in their proper Nourishment, so is this stone furnished with the powers of drawing in Iron as its proper *Pabulum* ".

In general, we are told, the materials of the flesh " lye like leaves in a book or the pielings of an onion ; dibbing to the two Poles and rising towards the Aequator " ; exceptions to the rule occur " Upon the coasts of the Sea where they have their Dibb to the Sea, and Rise to the Shore ".

Discussing water, the earth's blood, Robinson says : " In the Earth there is a constant circulation of water, as in other Animals of Blood," but he adds, " [springs] are neither the off-spring of the sea, nor are they . . . derived from Rains or Dew, as several of the old Philosophers have variously guessed and fancy'd. . . . That they do not come from the Sea is evident from the natural Dibb of metals into the Sea and their Rise to the Shore ; which makes it impossible for the Salt-water to penetrate them ; . . . besides, if we sink a Pit upon the Sea-shore, and carry a Drift some hundreds of Yards under the Salt-water, we find still the natural Feeders of Coal or stone without the least mixture of salt. . . . That they owe not their Original to the Dews or Rain should be (methinks) evident to the Eyes of all men ; . . . For the Rains (which are drawn up in Vapours, by the Sun's influence, from the Sea ; and afterwards being condens'd in the Air, drop down in Showers) do onely moisten and refresh the outward Skin and Surface of the Earth ; and descend no further than is requisite for the necessary Sustenance of Plants, and for the supplying the common occasions of Man and other parts of the sensitive World."

Having shown that the opinions of others respecting springs were untenable, he proceeded to put forward his own views and pointed out that " Tho' the most rapid Springs do break out and flow from the tops of the highest Mountains, and thence become the Heads of the greatest Rivers in the world, yet these Springs may be drawn down, and the Mountains tapp'd and dreign'd, by Cross-cutting (with a Level-Drift) those Metals and Minerals, whose natural Feeders they are, and from whence they flow ; and such Mountains, thus drawn dry, will fire of themselves. For the hot and fiery Spirits of Sulphur, together with the fat and unctuous ones of Bitumen and Coal (being now freed from the Shackles of the cool Feeders) uniting their forces, break out in Eruptions of Fire and Smoak ; which has occasion'd all the wonders, we read off, at Mount *Aetna* and other flaming Mountains ".

One of the principal reasons " why Springs or Feeders break out more frequently, and flow more Rapidly, from the tops and skirts of Mountains, than from the plain and level Ground " is that " the height of the Mountains exposes them to the violence of Storms, Tempests, and Thunder, which sometimes break their Veins ; but these Accidents seldom happen on the Levels, where the Earth's Grand-cover shelters both Metals and Feeders from such violences. And thus, in our own Bodies, 'tis much easier to break a Vein in the

Neck or Arm, where they lye nearest the Skin ; than in the Buttocks, or any other such Fleshy-part ".

Since the earth is to be given animal attributes it is not surprising to find that she perspires, for " *Damps* in Coaleries and other Mines proceed from the unctuous and fiery Spirits of Coal and Sulphur, which continually perspire out of the Coal-wall ".

Just as the bones of an animal are bound together by ligaments and sinews, so the Bones of the Earth are bound together by dykes and " rakes " which rise from centre to the surface, " dividing and cross-cutting all the flat metals and minerals."

Chapter 8 is devoted to " A Description of the Belly of the Earth, and what it may be suppos'd to contain ; with an Enquiry into the Causes of Hurricanes and Earth-quakes ". We are reminded that " Philosophers and Mathematicians, who consider how small a Proportion the deepest Shaft bears to the Diameter of the whole Earth, reflect on all the Works of Miners as Scratches rather in her Skin than Wounds in her Bowels ". For all this, however, " we may be allowed to make a Conjecture at the Nature of the *things that are not seen.*" and the conjecture we are invited to consider is that " in the Middle of the Earth there is a vast Cavity or Hollow, of a Regular Multangular Figure ". The cavity is " fill'd up with a crude and undigested Matter, endued with several different and contrary qualities which are in a continual Struggle and Contention among themselves. . . . Now, when in the Intestine War below, the Airy Particles prevail they break through the Joynts of the Earth in *Hurricanes* . . . And when (on the contrary) the fiery Particles are predominant, they force their Passage the same way, . . . causing, thereby flaming Eruptions and *Earth-quakes* ; sometimes with that Violence as to break the very Ribbs of the Earth, swallowing up Houses and Towns. And these Convulsions are as natural to the Earth as Feavers, Agues, and other Distempers, are to the Bodies of other Animals ".

It would seem that the Diurnal Motion of the Earth is due to a condition of chronic indigestion, for it " is caused by that vast Quantity of confus'd and undigested Matter, which is contained, and imprison'd in the *Belly of it* : For this Matter, consisting most of hot and fiery Particles, and such as are of an active and volatile Nature and Quality ; which cannot rest, nor be fix'd *in Loco*, must of necessity move in a regular and perpetual Round or Circle ".

Turning to astronomical matters we learn that the moon is not to be regarded as the cause of the Ebbing and Flowing of the tide, because, although the tide " keeps time with the Moon's Motion in its Increase and Decrease ; yet from hence it ought no more to be argu'd that the Moon contributes to the Sea's Motion than 'tis reasonable to conclude that one Man is the Cause of another's Running, who runs the same Race with him Shoulder by Shoulder, and Foot by Foot ". Our author's explanation is simple in the extreme ; it is just that " The *Ebbing* therefore and *Flowing* of the

Sea is its own natural Motion ", and in an equally simple way he dismisses all the difficulties connected with the movements of the heavenly bodies, for " what more agreeable to Common Sense than to believe that Divine Providence has communicated such a Motion to the Earth, as will most readily solve all the *Phaenomena* of the Heavenly Bodies in their suppos'd Motions ? "

Even if we cannot attribute to the moon the benefits we derive from the tides, we still owe her a debt of gratitude, for she " is indeed, in many particulars very kind and Serviceable to the Earth ", returning to it " that Light which it self does but borrow from the Sun " ; at the same time it beats down " those Vapours and Exhalations which arise from the Sea ", and when the moon is full, the " Sun's *Globuli* of Light, being thence darted back to us in a streight Line, bring with them some of the Moon's Moisture ; in the same manner as a Tennis-Ball, rebounding from a whiten'd Wall, brings to our hand part of the Colour with it. And this is the Reason why we have the greatest Hoar-Frosts and Dews in the Full of the Moon ; and why also, at that time, the moist Brains of such Madmen as (for that Reason) we call Lunaticks are most undisturb'd."

Mr. Robinson concludes his essay by pointing out that " The Reader is only presented with a rude Draught, and the first lines of a New Hypothesis ; which (if these Features take) may easily have its Proportions fill'd up and be drawn at full length hereafter ".

It is to be feared that the Features did not take, for there does not appear to be any work in which the rude draught was expanded into well-established Theory. Robinson did, however, have something to say about fossils in the *Essay towards a Natural History of Westmorland and Cumberland* which he published in 1709. He was unwilling to accept the view, generally held, that fossils were the relics of the Flood, because they were so often completely embedded in solid rock, and noticing that whereas *shell fish* were abundant as fossils, ordinary fish were rarely found, he suggested that " it seems more likely that when God from the Division of the Water made the dry land to appear, those shell fish which were not Locomotive were left behind, and by the general Petrifaction with the rest of the now solid strata were petrified into stone ".

This was by no means the most startling of his suggestions, but, like the child who has delivered a runaway-knock, he did not seem keen to have the matter more closely investigated, and hastened to add " but because I would not willingly over-burthen the Credulity of the Reader I will proceed to the next Chapter " !

Pre-Cambrian Association.

A. Present Position.

By Dr. E. H. Kranck.

B. Second Excursion, Scotland, 18th August—2nd September, 1934.

By Prof. E. B. Bailey and Dr. W. J. McCallien.

(PLATE XXVI.)

A. Present Position.

The Pre-Cambrian Association (Association Internationale pour l'Étude du Précambrien et des Vieilles Chaînes de Montagnes) was founded through the efforts of the late Professor J. J. Sederholm. It held its first excursion in Finland, 1931. Officers were elected, including Professor Sederholm as President and Drs. C. E. Wegmann and E. H. Kranck as Secretaries, but no definite policy was adopted. Since then about 130 geologists from many different parts of the world have expressed their interest in the enterprise. At the International Geological Congress in Washington, 1933, two meetings of the Association were held, and Professor E. B. Bailey was asked to organize an excursion to Scotland. This invitation he accepted for 1934, with Dr. W. J. McCallien as local secretary. In anticipation of the Scottish excursion Professor Sederholm and Dr. Kranck, in the absence of Dr. Wegmann, drafted provisional by-laws, and these were circulated.

During the Scottish excursion, which was attended by twenty-six members, representing thirteen nationalities, a business meeting was held at Lochinver on 29th August, 1934. Professor Bailey as Vice-President, acted as Chairman, and Dr. Kranck as Secretary. Professor Bailey opened with a short speech in honour of the late Founder.

The organization of the Association gave rise to lively discussion. It was agreed that a central organization was very desirable to maintain continuity between excursions. It was also decided to elect a Council and to ask it to prepare a revised draft of by-laws for future consideration. Meanwhile, the Association would be guided by the following rules :—

(1) The Pre-Cambrian Association is a friendly union of persons interested in the comparative study of Pre-Cambrian problems and of old mountain chains. It aims at an exchange of ideas and at organization of international excursions.

(2) Business meetings will be held during the excursions of the Association and during sessions of the International Geological Congress.

(3) The membership fee is ten shillings. This fee covers the period from the start of one excursion to the start of the next. Membership is compulsory for those who enter for an excursion, and the fee must be paid on entry. Membership is also open to well-wishers even if they do not intend to participate in an excursion.

(4) The cost of excursions, except for unforeseen expenses due to late withdrawals, must be paid by the participants. Association funds are intended for publication, postage, and incidental expenses.

(5) The Council of the Association consists of :—

President, elected from the next country to be visited.

Vice-President.

Two Secretaries, one nominated from the President's country to act as Local Secretary ; the other to act as General Secretary and Treasurer.

Additional members of Council as required.

(6) The President and Local Secretary will take office (*in absentia* if necessary) at a meeting held during an International Geological Congress. It will be their duty to organize the forthcoming excursion and subsequently to furnish a report. It is hoped that excursion reports will be published in some established journal of the country visited. They will be distributed free to members of the Association.

(7) The records of the Treasurer shall be examined by two Accountants selected by the Council.

The following Council was elected :—

President : Professor E. B. Bailey.
Vice-President : Professor P. Eskola.
Secretaries : Dr. E. H. Kranck and Dr. W. J. McCallien.
Members : Professor R. Kettner, Dr. H. von Eckermann, Miss A. I. Jonas, Professor M. B. Baker.

The third excursion of the Association will be held in Czechoslovakia, probably one year after the International Geological Congress in Russia. Professor R. Kettner has been asked to prepare it. Sweden was mentioned as the probable site of the fourth excursion.

A *compte rendu* of the first excursion in Finland, 1931, was prepared by Drs. Wegmann and Kranck and published by Professor Sederholm, Helsingfors, May, 1933. The report of the second excursion is given below in such a form as may be of use to future visitors to Scotland.

Applications and subscriptions for membership should be sent to Dr. E. H. Kranck, 5 Engelplatsen, Helsingfors, Finland.

B. Second Excursion, Scotland, 18th August–2nd September, 1934.

18th August. Glasgow to Ballachulish.

The party of twenty-six assembled at Glasgow University, where Professor Bailey outlined the main geological interests of districts about to be visited. The University entertained the Association to luncheon, and Principal Sir Robert Rait referred to the loss which had been suffered through the death of the President, Professor J. J. Sederholm. Professor C. F. Kolderup replied.

At 2 p.m. the party left in private buses for Ballachulish (4).[1] The first stop was at Luss slate quarry on Loch Lomondside, where Professor C. E. Tilley gave an account of the metamorphism of the Southern Highlands (1). Subsequent halts allowed of examination of albite-schists at the roadside north of Ardlui, Loch Tay Limestone and associated epidiorite in a quarry a short distance north-west of Crianlarich, and the view at the western end of the Glencoe Cauldron Subsidence (2, pl. xxxii; 5, figs. 13, 14). In the evening at Ballachulish Professor Bailey discussed the geology of the surrounding country (3; 4; 5, chap. v; 6–9).

19th August. Ballachulish.

The Ballachulish granite and hornfelsed Leven Schists were crossed east of the Ballachulish Hotel (5, fig. 32). Thereafter the day was spent in confirming the existence of a number of slides. Professor Bailey began by explaining the geology of the hill-side above St. John's Church, where Appin Phyllites, Appin Limestone, Appin Quartzite, and Striped Series occur in the centre of a downfold called after Beinn Bhan. Considerable time was devoted to the study of the shore and railway section immediately west of the church, and all agreed that the Ballachulish Slates, though well developed in the eastern limb of the downfold, are entirely cut out from the western limb. This indicated an important slide, called the Ballachulish Slide (5, pp. 47, 48). The party then went a short distance inland south of the church and found good current bedding in pebbly Appin Quartzite, so oriented as to indicate that this quartzite is younger than the Ballachulish Slates (9). The latter were seen in large quarries at the village, and beyond them at the roadside the grey and comparatively pure margin of the Ballachulish Limestone (5, p. 46).

Gleann an Fhiodh was next studied (5, pp. 48, 49). In the main river a slide cuts out Appin Limestone from between big developments of Appin Quartzite and Appin Phyllites; while a little farther upstream, in a tributary coming in from the east, another slide leaves the Appin Limestone intact, and, instead, reduces the Appin Quartzite to about 18 inches in thickness. On the hill-side to the east Ballachulish Slates have been worked for roofing slates. Following their outcrop the party reached a good exposure of Ballachulish Limestone crossing an important tributary, Allt Socaich. This group is in part a pure grey limestone and in part mere calcareous schist, with a thin cream-coloured limestone edge followed by Leven Schists farther upstream. It was pointed out that on the steep hill-side to the south (Sgorr a' Choise) only this cream-coloured edge continues to separate Ballachulish Slates and Leven Schists, thus affording clear evidence of still another slide. The return journey was made on the north side of Gleann an Fhiodh.

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[1] The numbers in parentheses refer to References at end of article.

After dinner members visited the kentallenite and associated pegmatites at Kentallen, and Appin Quartzite in quarries a mile farther south.

20th August. Ballachulish to Fort William.

The party examined the southern coast section of Loch Leven on the roadside and foreshore near the boathouse and pier, north of Bridge of Coe. After crossing a typical exposure of the very impure portion of the Ballachulish Limestone and a narrow outcrop of Ballachulish Slates, they saw evidence for a slide, separating Appin Quartzite from Leven Schists (5, p. 56). Professor Bailey claimed this slide as a folded repetition of the Ballachulish Slide seen on 19th August, but deferred further evidence until the following day. Meanwhile, in a traverse starting at Caolasnacon he demonstrated by the use of current bedding the existence of two quartzites older than the Glencoe Quartzite (Mr. R. G. Carruthers's reading of the succession, see 9—advance proofs of the illustrations were in the hands of the party). The current bedding observed in this traverse, and again at Kinlochleven and along the neighbouring north shore of the loch, brought home very vividly the reality and extent of a great inversion, known as the Kinlochleven Inversion (9).

On the way to Fort William a stop was made to examine the current bedding of the Appin Quartzite east of Onich. As T. Vogt first recognized, this shows that the Appin Quartzite is younger than the Ballachulish Slates (6, p. 71).

21st August. Fort William.

From Fort William the party motored back to the Callert district on Loch Leven (5, pp. 40–5). They walked across the Ballachulish Fold on the northern shore of the loch, giving special attention to two outcrops, eastern and western, ascribed to the Ballachulish Slide. In spite of bad weather, some members went up the hill-side to beyond the summit of the pass and confirmed the zigzag nature of the eastern slide outcrop. They agreed, on this and other evidence, that the eastern slide had been rightly interpreted as a folded reappearance of the western slide, that is of the Ballachulish Slide of the type outcrop. They then walked westward across an exposure of Appin Quartzite, and verified the upfold nature of the Tom Meadhoin Outcrop of Glencoe Quartzite. They also checked Vogt's observations regarding its current bedding (6, pp. 70, 71).

In the evening Professor Bailey gave a talk on the geology of Ben Nevis (5, chap. x).

22nd August. Fort William to Dingwall.

Leaving Fort William for the north, a stop was made at a quarry in Eilde Flags at the old Glen Nevis Bridge. Then a detour was undertaken up Glen Nevis to beyond Glen Nevis House. The party saw clearly on the hill-side the downfold structure of the Appin Fold, brought out in the landscape by a core of Ballachulish Slates underlain by Ballachulish Limestone, the lower impure part of which is altered by the Ben Nevis Granite to calc-silicate-hornfels. In this section the asymmetrical nature of the fold, with Leven Schists on one side and Eilde Flags on the other, is easily appreciated. Professor Bailey explained that this asymmetry was due to the presence of the Fort William Slide cutting out several formations from between the Ballachulish Limestone and Eilde Flags (5, p. 32; 9). From Glen Nevis the party continued to the Spean section beyond Spean Bridge, where an exposure at the railway bridge showed a stratigraphical passage from Eilde Flags to Eilde Quartzite. Current bedding, not hitherto observed at this locality, indicated that the quartzite turns its younger side away from the flags. The party then walked across the Fort William Slide, which, as at Glen Nevis, introduces a wide outcrop of Ballachulish Limestone with garnetiferous Leven Schists beyond (3, p. 602).

The lowest of the parallel roads of Glen Roy was seen.

Continuing via the Great Glen and Inverness to Dingwall, the party stopped at Loch Ness to examine Moine Flags and Middle Old Red Sandstone.

23rd August. Dingwall to Helmsdale.

From Dingwall the party motored to Loch Bad a' Bhathaich, on the Ardross estate, about 5 miles south-east of Carn Chuinneag (11), and examined the garnetiferous Moines outside the contact aureole of the Carn Chuinneag (Inchbae) augen-gneiss. The hornfelses have to a large extent escaped regional metamorphism (10; 12, pp. 73–8, chap. vi). Post-hornfels movement has, however, developed beautiful examples of boudinage structure. Inverted current bedding was seen in two places, but the significance of the observation must wait on further field work. Members walked a short distance into the outcrop of the augen-gneiss, and on the return journey were entertained at Kildermorie Lodge by Mr. G. S. Albright, who had accompanied them over the hills.

On the way to Helmsdale (13) Old Red conglomerates were seen at the Mound (14, p. 61), and a stop was made at Loth Bridge to examine an unconformity between Old Red Sandstone and the Helmsdale Granite (15, p. 437). A little downstream from this junction a recent flood had greatly improved an exposure of Kimmeridgian chasm-breccia (15, pp. 440–1), now seen for the first time in contact with the Old Red Standstone.

24th August. Helmsdale.

On account of their intimate genetic connection with earth-movements Kimmeridgian boulder beds were closely examined both north and south of Helmsdale (15, pp. 448–455). In the afternoon the party were entertained by Professor and Mrs. Walton at their camp on the dunes near Crackaig Point.

In the evening Professor H. H. Read explained the geology of Sheet 109 and surrounding country.

25th August. Helmsdale.

Under Professor Read's guidance the party motored up the Strath of Kildonan (Helmsdale River, 16), across outcrops of Helmsdale Granite and Moine Granulites and Pelites, to study the Strath Hallidale Injection-complex (17, chap. viii). A start was made in the Suisgill Burn (17, p. 155). Sillimanite-schists, invaded by multitudes of granite sheets, were first examined. A short distance from the road a few of the party spent some time successfully panning for gold (17, pp. 217–18). The remainder continued up the glen as far as the sillimanite-rich siliceous granulites of Cnoc na Beiste (17, p. 154). A very remarkable feature of the Suisgill district is the extent to which pre-glacially weathered rock has escaped erosion. On the return journey down the Strath of Kildonan, Moines were examined in a burn section about half a mile south-east of Kildonan, and found to be very little affected by injection (17, p. 155). The members were then entertained by Mr. Harold McCorquodale, at Salscraggie Lodge, and after tea they examined the junction of the porphyritic margin and non-porphyritic interior of the Helmsdale granite in the burn west of the lodge (17, p. 195).

26th August. Helmsdale to Inchnadamph and Altnacealgach (Aultnacallagach).

In Strath Fleet (13) several halts allowed of the examination under Professor Read's leadership of the Rogart Injection-complex (14, pp. 4, 5, 21, 22), with its zone of apophyses (14, pp. 39, 40), zone of inclusions (14, pp. 25–9, 33–6), and central granodiorite (14, pp. 22–5). At Oykell Bridge mullion structure in the Moines was carefully studied. The Moine Thrust was crossed close to Cnoc Chaorraidh (18). Here the Geological Survey shows intrusive sheets in the zone of mylonized Moine Schists above the thrust. One of these sheets was found, itself greatly mylonized. Professor Bailey pointed out that the occurrence of these sheets, just above the thrust as well as below, suggests that their intrusion period may be later than some part of the Moine Thrust movement, and not entirely earlier as is generally assumed.

Borolanite was collected at a roadside quarry (19, p. 442).

27th August. Inchnadamph and Altnacealgach.

Before breakfast some of the members staying at Altnacealgach went with Professor P. Eskola to the Allt a' Mhuilinn (Aultivullin Gorge) exposure of borolanite, 1½ miles east-south-east of the hotel. They discovered that the well-known sheared borolanite of this locality is in places cut by relatively unsheared pegmatites (Pl. XXVI). Drs. Peach and Horne have stated that the shearing of the borolanite " may have been produced by the post-Cambrian movements " responsible for the Moine Thrust (19, p. 524). If later work should confirm this suggestion then Professor Eskola's observation will show that the borolanite and pegmatite suite of intrusions, taken as a whole, overlaps in time some part of the Moine thrusting, instead of being altogether earlier as has been previously thought. The evidence, therefore, so far as it goes favours the inference drawn by Professor Bailey from the sheared intrusion examined on 26th August.

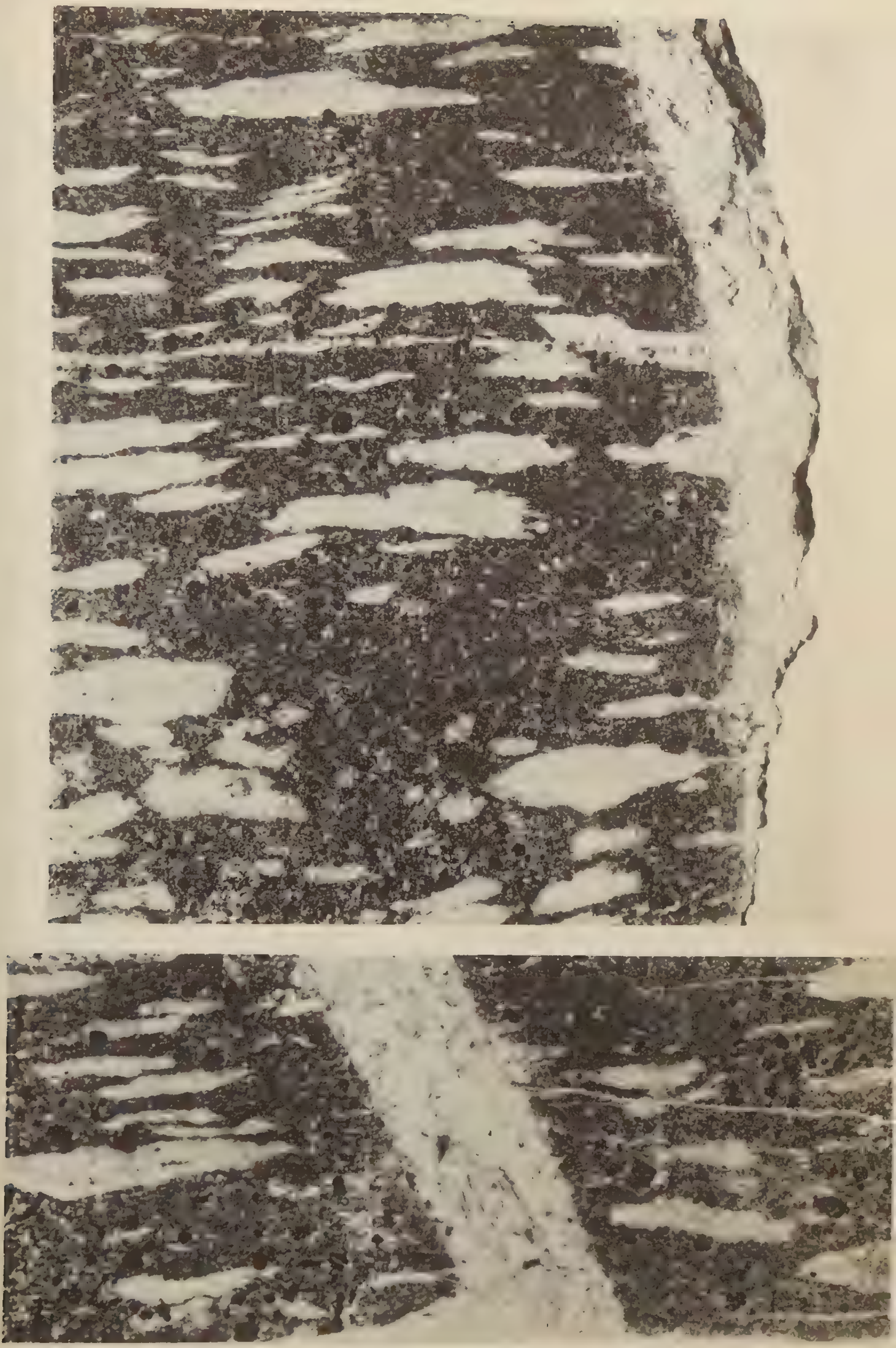
After breakfast the party motored by the shore of Loch Assynt to a quarry in the Basal Quartzite of the Cambrian. Looking across the loch a splendid view was obtained of the double unconformity on Beinn Gharbh (19, fig. 32).

From the basal quartzite the party walked back across the various members of the Cambrian as far as the Cambrian Limestones of the Schuppen Zone (20, pp. 12–15). They then motored by the Kylesku road to the bend at Loch na Gainmhich, and leaving the buses walked northwards over the outcrop of the Pipe Rock. Professor Bailey explained the diagrammatic view of the northern side of Loch Glencoul (20, fig. 5). The party then examined the Schuppen Zone and Glencoul Thrust as exposed along the path on the south side of the loch, and continued a short distance into the Lewisian of the Glencoul Nappe (20, fig. 4). The return journey to the buses followed the base of the Cambrian. Where first encountered the base of this formation rested directly on Lewisian, but presently it lifted up and allowed Torridonian arkoses to intervene.

Specimens were collected of Cambrian Limestone, contact-altered by Cnoc na Sroine Syenite, from a quarry by the roadside near Ledbeg (19, chap. xxxi), and of ledmorite from Ledmore Burn (21, p. 384).

28th August. Inchnadamph and Altnacealgach.

The excursion began by going up the Traligill Burn but turned north near the entry of the important tributary, Allt Poll na Droighinn, and on the slope examined both the Schuppen Zone and the Glencoul Thrust. Professor Bailey demonstrated how the Glencoul Thrust crosses this tributary just below a conspicuous waterfall in Pipe Rock, and then dies out in a south-easterly direction (22). The party examined the Traligill section, with its minor thrusts in the Cambrian Limestone, along one of which the stream



SHEARED BOROLANITE CUT BY UNSHEARED PEGMATITES (NATURAL SIZE) ALLT A
MHUILINN.

[To face p. 554.

disappears underground for a considerable distance. They continued across the pass to near the source of the Oykell, and took note of the Ben More Thrust and other structures of Conival (19, figs. 8, 9, in which the Glencoul Thrust has been wrongly identified). They returned in a south-westerly direction across a quartzite anticline and limestone moor with swallow holes to the Torridonian klippe of Beinn nan Cnaimhseag. They reached the road by Allt nan Uamh, which separates this klippe from its neighbour at Beinn an Fhuarain (20, fig. 11). The lower slopes of the valley are cut in Cambrian limestone with bone-bearing caves.

29th August. Inchnadamph and Altnacealgach.

The party motored by Loch Assynt to Lochinver, a little west of the special Assynt map (18). The first stop was made at the appearance of Torridonian Arkose from beneath the basal Cambrian Quartzite. The Torridonian was traversed on foot as far as a roadside quarry exhibiting a basal pebble bed resting on weathered Lewisian Gneiss. Some of the pebbles showed wind erosion (20, p. 11). Excellent exposures of pyroxene-gneiss cut by a prominent pre-Torridonian Basic Dyke were then examined between the road and the loch (19, pp. 160, 162). Special attention was also given to pre-Torridonian Shear Zones with production of biotite, as at Loch Assynt Lodge, Tomore (19, p. 166), to a pre-Torridonian ultrabasic dyke near the foot of the loch (19, pp. 85, 164), and to xenoliths and flow banding in gneiss on the shore at Lochinver.

30th August. Inchnadamph and Altnacealgach to Kinloch Rannoch.

Before setting out for Kinloch Rannoch (23) the whole party paid a visit to the Allt a' Mhuilinn section of sheared borolanite and relatively unsheared pegmatites (Pl. XXVI). The Knockan exposure of the Moine Thrust was examined (20, fig. 12). The Inchbae augen-gneiss was conspicuous at the river bridge west of Inchbae.

31st August and 1st September. Kinloch Rannoch.

Two days spent at Kinloch Rannoch (23) were devoted to a consideration of an extremely complicated problem in sliding and folding, an account of which is at present in preparation by Dr. W. J. McCallien and Professor E. B. Bailey. The party was furnished with a manuscript map and a typed statement of stratigraphy. Briefly the rocks are separable into two main divisions, Struan Flags referred to the Moines, and the remainder referred to the Dalradian. The stratigraphy of the Dalradian is as unravelled by Dr. E. M. Anderson (24), with the addition of a dolomitic group interstratified in the Schichallion Quartzite. The original order of succession adopted by Dr. Anderson has since been confirmed beyond question by Mr. A. Allison, working with current and grading bedding in the Islay archipelago (25). The Moines and Dalradians are separated by a major slide. The Dalradians are involved in several great folds and slides which do not penetrate this major slide. The Dalradian anticlinal folds are plunging, so that they close downwards. The Moine-Dalradian slide, and also the folds and slides affecting the Dalradian, have been involved in an intense later fold, responsible for the well-known extension of the Dalradian outcrop into the Moine area—which characterizes the Kinloch Rannoch district even on small-scale maps of the British Isles. It was argued that this later fold is in part a downfold and in part a torsional structure, and that there has been relative depression of pre-existing structures on its north-east side.

The 31st August excursion started from Tempar, 2 miles east of Kinloch Rannoch, to allow of examination of exposures in the Tempar Burn and along the northern foothills of Schichallion. The following were studied in turn: Schichallion Quartzite (younger division), Dolomitic Group, Schichallion Quartzite with siliceous pebble beds (older division), Schichallion Boulder Bed, Tempar Limestone, Banded Series, Grey Limestone, Grey Schist. The party rejoined the road south of Lochan an Daim and walked to Braes of Foss. Here they examined a good exposure of the Dolomitic Group (previously mistaken for part of the Grey Limestone) in the stream east of Cnoc nan Aighean, flowing from the south-west; and a little beyond a sheepfold they traced a slide that carries the outcrop of the Grey Limestone right across the type outcrop of Schichallion Quartzite. It was agreed that this slide is as clear as those that had recently been examined in the North-West Highlands.

On 1st September the same Dalradian succession was examined in Allt na Moine Buidhe, 3 miles north-east of Kinloch Rannoch. During the day the following additional formations were seen: Killiecrankie Schists, Carn Mairg Quartzite, Ben Eagach Schists, and Ben Lawers Schists. Two main point were made: (*a*) On Beinn a' Chuallaich an anticlinal fold of Schichallion Quartzite encloses a core of Schichallion Boulder Bed (24, p. 433). It was demonstrated that this core closed downwards; (*b*) At Carn Fiaclach, west of Beinn a' Chuallaich, Ben Lawers Schist is brought into contact with the Moine Flags beyond the main Moine-Dalradian slide. This relationship had already been indicated by Dr. M. Macgregor south of Loch Rannoch (26).

2nd September. Kinloch Rannoch to Edinburgh.

The party motored to Edinburgh to take part in the Centenary Celebrations of the Edinburgh Geological Society, held 3rd–4th September, under the Presidency of Sir John S. Flett. A stop was made at Stirling Castle to examine the quartz-dolerite sill and the wonderfully instructive geological and historical view.

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REVIEWS.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1933. Part I: 1*s.* 6*d.* Part II: 3*s.* Published by His Majesty's Stationery Office, 1934.

THE Officers of the Geological Survey have been largely occupied during the past year with the move into new quarters, hence field work has been somewhat necessarily curtailed, and there is little in Part I of the Report that calls for special remark. As usual, however, the series of short papers in Part II provide several features of considerable interest and importance. There are in all nine of these, and six of them deal with some aspects of Carboniferous stratigraphy and palaeontology; this is only as it should be, considering that the revision of the Coalfields has been the chief work of the Survey in recent years. Of the six, four are mainly concerned with the conclusions that may be drawn from the distribution of the Goniatites and freshwater (non-marine) Mollusca. In this connection the paper by Dr. M. Macgregor and Dr. Pringle on the Scottish Millstone Grit is especially noteworthy. They draw attention to the evidence of a stratigraphical break of considerable magnitude within the Millstone Grit of Scotland; this appears to indicate actual emergence of the Scottish area during the deposition of the beds of zones R and H in the south. The adoption of the base of zone E as the limit of the Millstone Grit necessitates the placing within that Series of the Upper Limestone Group and perhaps the whole of the Limestone Coal Group of Scotland; on the other hand, the suggestion that there was in some parts of England and Wales within zone H a transition from a lower to an upper Carboniferous flora is probably significant; so that if the goniatite-boundary had been drawn at the *top* of E instead of at the base, Bisat's "Lancastrian" would have agreed closely with Kidston's "Lanarkian".

In two further papers Dr. Wright draws attention to the difficulties encountered in making a classification of the Lower Coal Measures of Lancashire on the basis of the freshwater fauna; traced west from the Pennine region marine bands appear on new horizons, and the freshwater faunas become considerably richer and more numerous, and necessitate the creation of several subzones. Many new forms are figured and described, and attention once again directed to the variation displayed by these fossils.

Dr. Crookall contributes a useful paper dealing with "The Distribution of British Plant Incrustations", in which he gives the characteristic plant assemblages within the Lanarkian, Lower and Upper Yorkian, Staffordian, and Radstockian stages.

Dr. M. Macgregor and W. Manson describe the Carboniferous outlier of Inniemore, Morvern, and show that there is a greater thickness of Carboniferous rocks there than has hitherto been recognized.

The results of two borings are important; one from Huddersfield, in Yorkshire, has yielded Lower Coal Measure fossils from both freshwater and marine bands; this bore is dealt with by Dr. Wray, Dr. Jackson, and Professor Trueman. The second is a bore at Stonefold Farm, Berwickshire, which has yielded evidence of the Upper O.R.S. age of a volcanic episode hitherto relegated to the Carboniferous; it is described by W. Manson, with petrological notes by Dr. Phemister.

The two remaining papers are (*a*) an interesting description by Sir John Flett of a thomsonized xenolith in the Blackness teschenite sill, and (*b*) a notice of the occurrence of fossiliferous Salopian pebbles in the Peel Sandstones (Isle of Man). The fossils are mainly corals and bryozoa and some new forms are figured and described.

G. L. E.

KATALOG DER IN DEN ÖSTERREICHISCHEN SAMMLUNGEN BEFINDLICHEN SÄUGETIERRESTE DES JUNGTERTIÄRS ÖSTERREICHS UND DER RANDGEBIETE. JULIUS PIA and OTTO SICKENBERG. Denkschriften des Naturhist. Mus., Wien. Bd. 4. pp. i–xvi, 1–544. Leipzig and Wien: Franz Deuticke, 1934. Mk. 30.

IT is remarked in the preface that the economic position, which so severely restricted fresh accessions to museums, may yet be of service if it has enabled the rather limited scientific staffs to carry out more exhaustive work on the collections in their charge. In the present instance, whilst regretting the cause, one can but congratulate the authors on the effect, for this catalogue, though not descriptive, constitutes a useful work of reference and helps to render much more accessible to palaeontologists the rich collections of Neogene Mammalia in the various Austrian museums.

The arrangement of the work is zoological; within each sub-class are grouped the various families, within which fossil remains are mostly listed, not by genera, but under the categories of complete (or nearly complete) skeletons, skulls, lower jaws, teeth, vertebrae, and fore- and hind-limbs. Naturally this arrangement often causes the same genus to appear several times at different places in the list of any given family, but the very complete indexing enables the reader to track down specimens of a desired genus without much difficulty. In all, nearly 4,000 specimens are catalogued, comprising material from apparently all the University and Public Museums of Austria, and two private collections in Vienna.

At the end of the volume appear a systematic table of contents; a species index; a geographically arranged list of localities, with the genera represented; a systematically arranged index of the contents of each of the collections drawn upon in the catalogue; and a bibliography containing the full titles of the papers cited in brief in the main part of the volume. The addition of an index of genera would have been an advantage, for the table of contents does not quite fill this need.

O. M. B. B.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

Anniversary Meeting, 1st November.

Dr. L. J. Spencer: Murnpeowie (South Australia), a granular type of meteoric iron. This fine mass, found in 1909, weighing 2,520 lb., is preserved in the School of Mines, Adelaide. Study of an etched slice shows remnants of an original lamellar octahedral structure from which granular kamacite has been developed by heat treatment of the mass. The grains of kamacite are irregular in outline and orientation, and show well-marked Neumann lines. A narrow, finely granular zone on the outside of the mass shows the effect of another and later heat treatment during the flight of the meteorite through the earth's atmosphere.

Mr. J. Adam Watson: Colour reactions in the micro-chemical determination of minerals. Most of the elements occurring in minerals can be determined qualitatively by highly sensitive colour reactions carried out in solutions prepared from minute quantities of the minerals. Solution is effected either with HCl or by fusing in a bead of sodium carbonate in a loop of platinum wire. The basis of the work is mainly Dr. F. Feigl's *Qualitative Analyse mit Hilfe der Tüpfelreactionen*, published in 1931.

Mr. A. R. Alderman: Almandine from Botallack, Cornwall. Well crystallized, icositetrahedral garnets from Botallack, Cornwall, give the following analysis: SiO_2, 35·58; TiO_2, trace; Al_2O_3, 21·94; Fe_2O_3, none; FeO, 38·54; MnO, 0·70; MgO, 0·68; CaO, 1·68; H_2O, 0·12 = 99·24. The garnet is thus very rich in the almandine molecule. This, and many other analyses of almandine-rich garnets, show aluminium in excess of that required by the accepted garnet formula.

Mr. B. Lightfoot, Mr. A. M. Macgregor, and Mr. E. Golding: The meteoric stone seen to fall in the Mangwendi native reserve on 7th March, 1934. This is the first meteorite to be recorded from Rhodesia. It fell at 12.45 p.m., about 40 miles east of Salisbury, and was broken in its fall amongst granite boulders. The pieces recovered weighed 52¼ lb., but the whole must have been about 60 lb. The main mass, weighing 48 lb. 11 oz. (22 kg.), has been presented to the British Museum by the Government of Southern Rhodesia. It is a grey, chondritic stone of the Soko-Banja type, consisting of olivine, enstatite, and felspar with metallic nickel-iron (3·17 per cent) and troilite (4·98 per cent).

Mr. F. A. Bannister: The crystal-structure of the bismuth oxyhalides. Minute single crystals of BiOCl, BiOBr, and BiOI have been prepared by a diffusion method. They yield perfect Laue, rotation, and oscillation photographs, which show that all three salts are tetragonal and have a similar crystal structure to that of matlockite (PbFCl). The bismuth and oxygen atoms of these compounds are more closely packed together than the corresponding lead and fluorine atoms of matlockite. Powder photographs show that daubréeite (1876) is identical with artificial BiOCl.

The following were elected officers and members of Council: President, Sir Thomas H. Holland; Vice-Presidents, Mr. Arthur Russell, Sir William H. Bragg; Treasurer, Mr. F. N. Ashcroft; General Secretary, Mr. W. Campbell Smith; Foreign Secretary, Professor A. Hutchinson; Editor of the Journal, Dr. L. J. Spencer; Ordinary Members of Council, Professor P. G. H. Boswell, Professor H. L. Bowman, Dr. L. Hawkes, Mr. J. B. Scrivenor, Mr. T. Crook, Dr. W. F. P. McLintock, Mr. L. R. Wager, Dr. A. K. Wells, Professor A. Brammall, Mr. C. W. Mathews, Dr. T. C. Phemister, and Dr. H. H. Thomas.

CORRESPONDENCE.

NEW SECTIONS SHOWING THE JUNCTION OF THE CAMBRIAN AND PRE-CAMBRIAN AT NUNEATON

Sir,—On reading the contribution by L. J. Wills and F. W. Shotton on the above, I was reminded of the finding of a fragment of rock, regarded by Dr. Raw as probably Groby material, at Linthurst Brickworks, about 1½ miles S.S.W. of the Lickey Pre-Cambrian rocks and one mile N.E. of Burcot. The boulder is described in the *Proceedings* of the Birmingham Natural History and Philosophical Society, vol. xv, pt. ii, 1923.

Without venturing to connect this fragment with any supposed hidden markfieldite at the Lickey or Burcot itself, I suggest that if glacially derived, it would be legitimate to ascribe it perhaps to Nuneaton in preference to the more distant Charnwood area, and further that records should be made of any such material found in the Midlands.

W. F. Fleet.

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